A Study on the Texturing Design Guide Line of Concrete Pavement under Dynamic Load

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ABSTRACT

Cement concrete pavement is constructed by using various texturing methods for providing cautions to drivers and enhancing frictional resistance. The surface texture could be changed by texturing methods, resulting in the increase of dynamic load due to the speed variation of heavy vehicles. In order to evaluate the dynamic load increment in the section treated with surface texturing, four kinds of heavy vehicles (class-4, class-5, class-6 and class-7) are selected considering the passing frequency and damage effect on cement concrete pavement. In addition, artificial profiles with three types of grooving (general grooving, drainage grooving and warning grooving) are made by the texturing design guide of the cement concrete pavement.
From the dynamic analysis, dynamic load increases up to 2.23% and 1.47% in the general grooving and drainage grooving, respectively, which shows those grooving types have a little dynamic effects on the surface of cement concrete pavement. However, in the warning grooving, dynamic load highly increases up to 10.09%, so that additional analyses are performed at the condition of the pavement with warning grooving at various width and spacing.
From the analyses, it is found that dynamic load increment in maximal when width and spacing of warning grooving are combination of width 10 cm, spacing 30 cm and width 6 cm, spacing 30 cm. Dynamic load increment of class-7 heavy vehicle in shown by 20% or more compared to other vehicles at the same speed. In order to evaluate dynamic load amplification factor at different warning grooving width and spacing, dynamic load increments for the several representative vehicles are compared. The results show that dynamic load is not as much affected by the width of the warning grooving as the spacing. Especially when the spacing of the warning grooving is 3 m, dynamic load increment is minimal.
This study has performed additional analyses of the divided spacing of warning grooving. From the results, it is found that the conditions with width 6 cm, spacing between 150 cm and 250 cm in the warning grooving make it possible to minimize the impacts of dynamic load.

1. INTRODUCTION

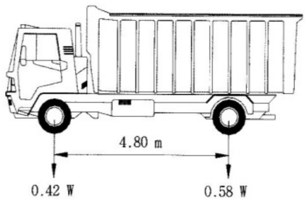
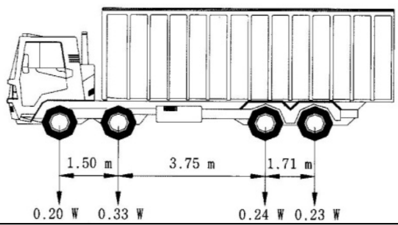
Cement concrete pavement should be implemented by various method of construction for the caution to the drivers and enhance of frictional resistance entailed on consecutive impact of joint. Because of this, it has been involved that not only the surface texture has been locally changed and that but also the increase in dynamic loads has resulted from the speed of heavy vehicle.

Along with the speed increase in a heavy vehicle and the change in road roughness, the increase in dynamic loads has directly applied to pavement surface being able to causing initial

damage. Therefore, it is imperative that we research for the way to calculate the dynamic loads followed by speed change of a heavy vehicle and understand the characteristics of the surface texture leading to the roughness of cement concrete pavement. As a fundamental material, the calculated dynamic loads could be utilized to decide to design the cement concrete pavement and plan the proper period for maintenance.

2. A Study on the Texturing Design Guide of Cement Concrete Pavement under Dynamic Load

Cement concrete pavement is constructed by using various texturing methods for providing cautions to drivers and enhancing frictional resistance. The surface texture could be changed by texturing methods, resulting in the increase of dynamic load due to the speed variation of heavy vehicles. In order to evaluate the dynamic load increment in the section treated with surface texturing, four kinds of heavy vehicles (class-4, class-5, class-6 and class-7) are selected considering the passing frequency and damage effect on cement concrete pavement (Figure 1). In addition, artificial profiles with three types of grooving (general grooving, drainage grooving and warning grooving) are made by the texturing design guide of the cement concrete pavement (Figure 2).

<table>
<tr><th></th><th colspan="3">The specific representation of heavy vehicle</th></tr>
<tr><td>Two axles heavy vehicle (class-4)</td><td>
</td><td>Four axles heavy vehicle (class-6)</td><td>
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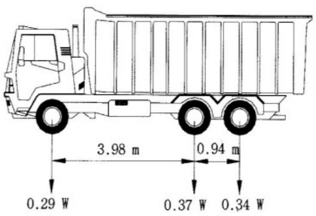
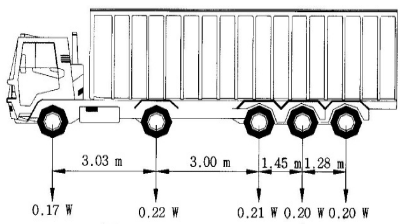
<tr><td>Three axles heavy vehicle (class-5)</td><td>
</td><td>Five axles heavy vehicle (class-7)</td><td>
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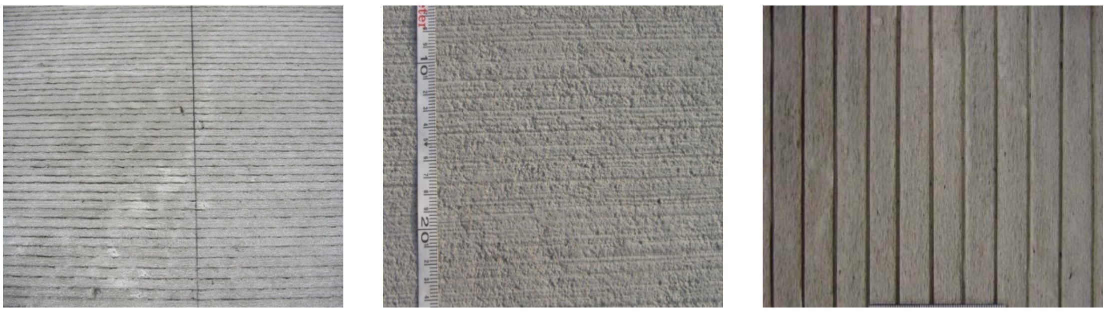
Figure 1. The specific representation of heavy vehicle [1]



(a) Tinning (b) Micro texture (c) Grooving

Figure 2. Type of surface texturing on cement concrete pavement [2]

In this study, it is presented that representatives of the heavy vehicles have been selected as considered frequency the effect of damage in cement concrete pavement. Table 1 shows the vehicle passing frequency on the cement concrete pavement in this study.

Table 1. Vehicle passing frequency on cement concrete pavement in Korea expressways [3]

Vehicle type	Vehicle passing frequency of cement concrete pavement (%)		
Class of heavy vehicle	Chung-bu Highway	2nd Chung-bu Highway	Chung-bu inland Highway
Small-class heavy vehicle	1.2	1.3	2.3
Normal-class heavy vehicle	67.8	81.9	55.1
Large-class heavy vehicle	9.9	6.6	19
Special I - class heavy vehicle	20.5	10.2	23.1
Special II - class heavy vehicle	0.6	0.1	0.6

In this study, the vehicle passing frequency of cement concrete pavement is used to select the heavy vehicle class. Figure 1 presents the representation heavy vehicles for this study and it is proposed the artificial profile based on the texturing design guide.

By being appointed the representative speed as an average speed concept, it is calculated the changing quantity of the dynamic loads which are entailed with change of road roughness affected by the speed of heavy vehicles.

According to the texturing design guide of general grooving, drainage grooving, and warning grooving, it is proposed to an artificial profile. As a result of analysis of dynamic loads, Table 2 shows that, while the general grooving and the drainage grooving has increased up to 2.23 % and 1.47 % each, which has little impact, the warning grooving has increased up to 10.09 %, which is necessary enough to get to be researched.

Table 2. Dynamic load amplification on various grooving types of cement concrete pavement

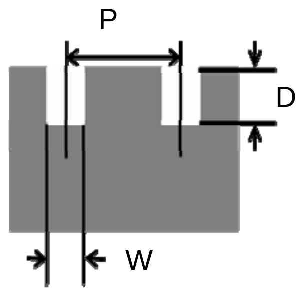
Grooving types	Texturing design guide for dynamic loads	Dynamic loads
General grooving	width 0.3 cm, spacing 0.3 cm	2.23%
Drainage grooving	width 5 cm, spacing 3000 cm	1.47%
Warning grooving	width 6 cm, spacing 30 cm	10.09%

In this study, artificial profile of warning grooving is made use of design guide of the warning grooving, and the database is constructed by analyzing of the 144 cases(the representation heavy vehicles, average speeds of heavy vehicles and artificial profile of warning grooving) with Trucksim program. TruckSim is a software tool for simulating and analyzing the dynamic behavior of medium to heavy trucks, buses and articulated vehicles [4]. The dynamic loads is analyzed by artificial profile of warning grooving's design guide (Table 3). Table 4 presents the database of the dynamic load amplification factor.

It is concluded that the biggest changing aspects are; both are width 10 cm plus spacing 30 cm and width 6 cm plus spacing 30 cm in the warning grooving. Figure 3 shows that in case of class-7 heavy vehicle, it is regarded as the most dynamic load shown increase in more than 20% regardless of speed change.

In order to construe the change aspects of dynamic loads, it is asked to compare with the representative classes preceded by the fact, both width 6 cm and width 10 cm in the warning grooving, which is minimized the change quantity in dynamic loads. Especially, it is noted to refer width 3 cm in the warning grooving at the lowest.

Table 3. Warning grooving specification in Korea [5]



Warning grooving specification (mm)		
Depth (D)	Width (W)	Spacing (P)
10	60	300
	60 / 100	1000
	100	3000

Table 4. Dynamic loading amplification factors at various vehicle speeds and grooving specifications

Heavy vehicle	Speed (km/h)	width 30 cm		width 100 cm		width 300 cm	
		Spacing 6 cm	spacing 10 cm	spacing 6 cm	spacing 10 cm	spacing 6 cm	spacing 10 cm
class-4	5	1.1779	1.1855	1.1624	1.1703	1.0693	1.0547
	20	1.1396	1.1763	1.1028	1.1533	1.058	1.0356
	60	1.0948	1.163	1.0566	1.0681	1.0206	1.0182
	80	1.0911	1.1257	1.062	1.057	1.0095	1.0088
	110	1.0989	1.1144	1.0268	1.0504	1.026	1.011
	160	1.0934	1.113	1.051	1.0631	1.0268	1.0024
class-5	5	1.0892	1.098	1.058	1.067	1.043	1.0234
	20	1.0923	1.092	1.0502	1.06	1.0377	1.0192
	60	1.1009	1.084	1.0265	1.052	1.0226	1.012
	80	1.0872	1.076	1.0422	1.049	1.0189	1.0109
	110	1.0596	1.078	1.0242	1.0472	1.0049	1.0084
	160	1.0842	1.0851	1.0315	1.0421	1.0046	1.0026
class-6	5	1.0758	1.0859	1.0561	1.0592	1.0238	1.0226
	20	1.0715	1.0825	1.0476	1.057	1.0144	1.0215
	60	1.0869	1.0806	1.039	1.0541	1.0038	1.0201
	80	1.0751	1.0608	1.0316	1.0416	1.001	1.0016
	110	1.0932	1.0542	1.0438	1.0342	1.0152	1.0135
	160	1.0561	1.0611	1.0271	1.0389	1.0052	1.0125
class-7	5	1.2092	1.2315	1.1691	1.2243	1.0681	1.0756
	20	1.2012	1.218	1.1552	1.1912	1.059	1.073
	60	1.2202	1.211	1.1617	1.1819	1.052	1.0722
	80	1.2179	1.215	1.1632	1.187	1.048	1.0647
	110	1.2111	1.2156	1.1611	1.181	1.059	1.0554
	160	1.2096	1.2098	1.1605	1.1876	1.0528	1.0371

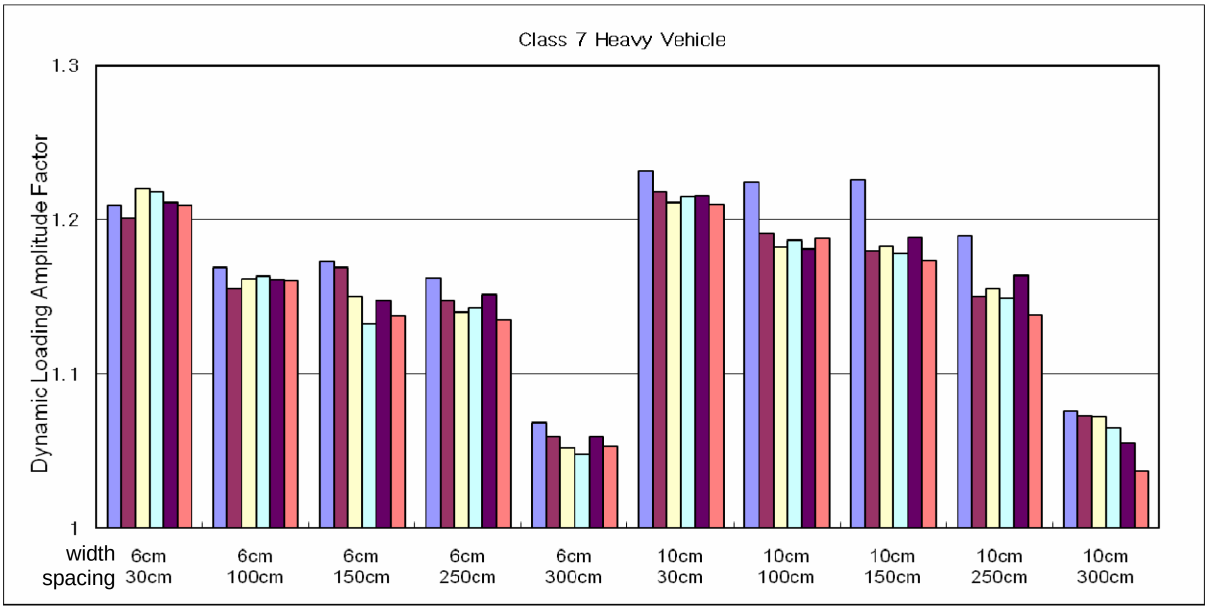


Figure 3. Dynamic load amplification factor for class-7 vehicle

Also, it has been designed to the dynamic load amplification factor involved with the change quantity in dynamic load which is divided based on the standard of the average dynamic axle load and we have made database on the texturing design guide of warning grooving and the dynamic load amplification factor referring to the 144 cases of driving speed of a heavy vehicles which are driven on the rough section by 5 km/h.

It proposed in addition that spacing elucidated let fixed to width 10 cm along with between spacing 1.5 m and 2.5 m, which is possible to minimize the impact of dynamic load among 4 classes of heavy vehicles. Table 5,6 and 7 is presented a less dynamic effect on the texturing design guide of warning grooving on the tollgate area, climbing lanes and high-speed lanes.

Table 5. The optimum texturing design guide of warning grooving nearby tollgate area

classification	average speed	The optimum texturing design guide of warning grooving(suggestion)	
		class-7 heavy vehicle	
		minimum dynamic load amplification factor	warning grooving
average speed	80 km/h	1.0480	width 6 cm spacing 300 cm
close to tollgate	60 km/h	1.1400	width 6 cm spacing 250 cm
very close to tollgate	20 km/h	1.1476	width 6 cm spacing 250 cm
after passing by tollgate	5 km/h	1.1623	width 6 cm spacing 250 cm

Table 6. The optimum texturing design guide of warning grooving on general expressway

classification	average speed	The optimum texturing design guide of warning grooving(suggestion)	
		class-7 heavy vehicle	
		minimum dynamic load amplification factor	warning grooving
average speed	80 km/h	1.0480	width 6 cm spacing 300 cm

Table 7. The optimum texturing design guide of warning grooving on climbing lanes

classification	average speed	The optimum texturing design guide of warning grooving(suggestion)	
		class-7 heavy vehicle	
		minimum dynamic load amplification factor	warning grooving
low lane slope / downhill lane	80 km/h	1.1328	width 6 cm spacing 150 cm
medium lane slope	60 km/h	1.1400	width 6 cm spacing 250 cm
high lane slope	20 km/h	1.1476	width 6 cm spacing 250 cm

4. CONCLUSIONS

Dynamic load increases up to 2.23% and 1.47% in the general grooving and drainage grooving, respectively, which shows those grooving types have a little dynamic effects on the surface of cement concrete pavement. However, in the warning grooving, dynamic load highly increases up to 10.09%, so that additional analyses are performed at the condition of the pavement with warning grooving at various width and spacing.

Also it is found that dynamic load increment in maximal when width and spacing of warning grooving are combination of width 10 cm, spacing 30 cm and width 6 cm, spacing 30 cm. Dynamic load increment of class-7 heavy vehicle in shown by 20% or more compared to other vehicles at the same speed. In order to evaluate dynamic load amplification factor at different warning grooving width and spacing, dynamic load increments for the several representative vehicles are compared. The results show that dynamic load is not as much affected by the width of the warning grooving as the spacing. Especially when the spacing of the warning grooving is 3 m, dynamic load increment is minimal.

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REFERANCES

[1] Korea Ministration of Construction & Transportation (2006), Vehicle classification guide, Korea Institute of Construction & Transportation

[2] Korea Ministration of Construction & Transportation (2002), Guide for installation of road safe facilities, Korea Ministration of Construction & Transportation

[3] Korea Ministration of Construction & Transportation (2006), Annual statistics report of Construction & Transportation, Korea Ministration of Construction & Transportation

[4] Mechanical Simulation Corporation Homepage, http://www.carsim.com

[5] RoadTech Homepage, http://www.groovinginfo.net